Force-sharing in Joint Lifting

Jurjen Bosga and Ruud G.J. Meulenbroek

Nijmegen Institute for Cognition and Information, Radboud University Nijmegen, The Netherlands

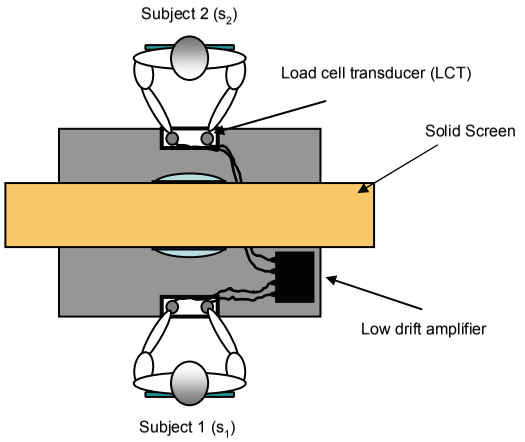
Introduction

A central issue in contemporary neuroscience is to come to grips with the coordination of redundant systems. Coupling of actuators into motor synergies is traditionally interpreted as a strategy for simplifying complex coordination problems (Cole and Abbs, 1986; Latash, 1999; D'Avella, Saltiel, & Bizzi, 2003). Negative covariation among finger force production is taken to indicate that individual fingers produce certain stable percentages of the total force (Li, Latash and Zatsiorsky, 1998a; Santello and Soechting, 2000; Dumont, Popovic, Keller and Sheikh, 2006). When *two* people perform an isometric-force (virtual lifting) task together, the system is overspecified and force-stabilizing synergies between the hands could, in principle, be formed. The aim of our study was to capture the essential features involved in dynamic force-sharing between two actors.

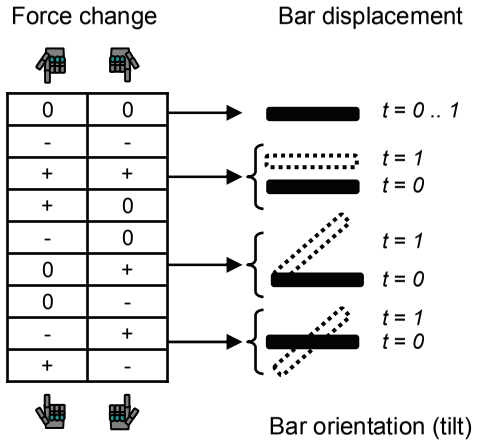
Method

Participants were seated vis-à-vis, at freestanding tables that were separated by a solid screen. A monitor was placed at eye-level in front of each participant. Upon the presentation of a visual go-signal participants were asked to lift a visually presented bar by generating an upward pressure with the left and right index finger on two load cell transducers. The bar had to be transported into a target area and *held* there for a 2-s period. Unbalanced force generation resulted in a tilt (rotation) of the bar in the frontal plane. Participants could not see each other and were not allowed to verbally communicate.

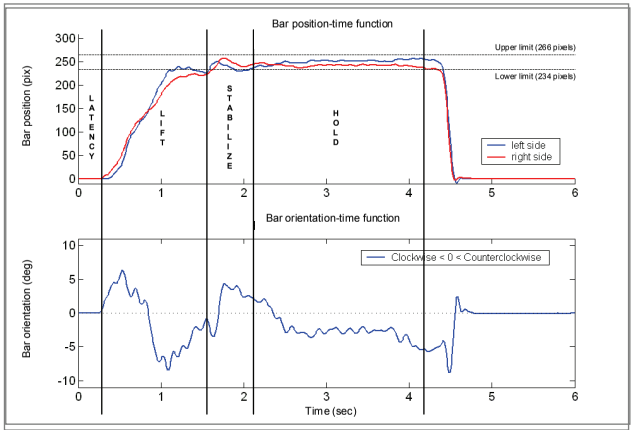
Experimental setup (Top view)



Experimental variables



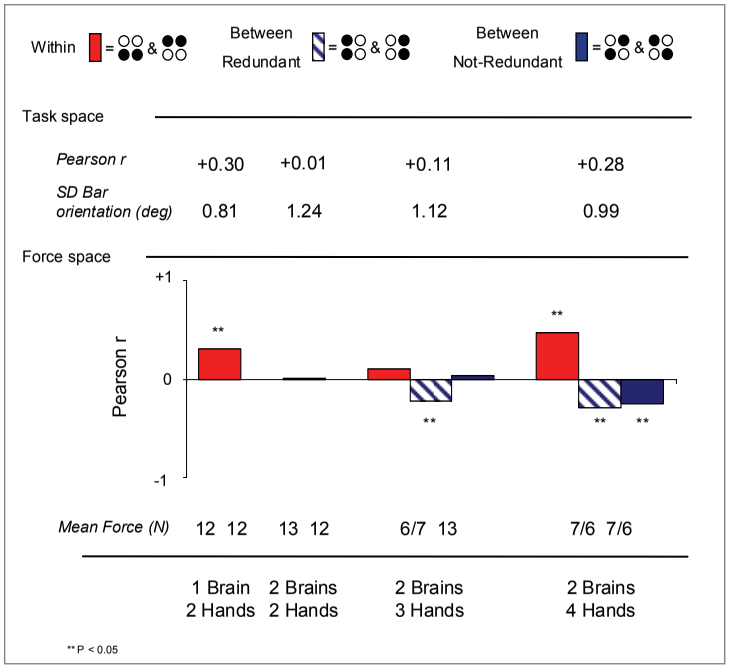
Preprocessing



Results

Participants were remarkably successful (85% of trials correct). On average, the latency in the two-hands/one-brain conditions was similar to that in the two-hands/two-brain condition (~ 270 ms) whereas the movement time during the lift phase was longer for joint-action than for single-action (1500 vs 1200 ms, resp.). However, even in redundant conditions the hands of the co-actors were tuned to each other.

Performance in hold phase of successful trials



Conclusions

The results confirm observations by Burstedt, Edin and Johansson on joint (non-virtual) lifting (1997). Furthermore, the joint co-ordination of forces:

- is as successful as the individual actions
- yields slower task performance
- increases performance error only marginally
- elicits equal distribution of task load
- proves beneficial for tasks that require maneuverability
- can be described by task-specific synergies

References

Burstedt, M.K.O., Edin, B.B., Johansson, R.S. (1997). Coordination of fingertip forces during human manipulation can emerge from independent neural networks controlling each engaged digit. *Experimental Brain Research, 117*, 67–79.

Cole, K.J. and Abbs, J.H. (1986). Coordination of three-joint digit move-ments for rapid finger-thumb grasp. *Journal of Neurophysiology, 55*, 1407-1423.

D'Avella, A., Saltiel, P. & Bizzi, E. (2003) Combinations of muscle synergies in the construction of a natural motor behavior. *Nature Neuroscience, 6*, 300-308.

Dumont, C.E., Popovic, M.R., Keller, T. and Sheikh, R. (2006). Dynamic force-sharing in multi-digit task. *Clinical Biomechanics, 21*, 138-46.

Latash, M.L. (1999). On the evolution of the notion of synergy. In *Motor Control, Today and Tomorrow.* Gantchev,G. et al (eds.), pp. 181-196, Sofia.

Li, Z-M., Latash, M.L. & Zatsiorsky, V.L. (1998a). Force sharing among fingers as a model of the redundancy problem. *Experimental Brain Research, 119*, 276-286.

Santello, M. and Soechting J. M., (2000). Force synergies for multifingered grasping. *Experimental Brain Research, 133*, 457-467.

Acknowledgements

This work was supported by FP6-IST2 EU project 003747, JAST

bosga@xs4all.nl